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ASSOCIATE COMMITTEE ON HYDROLOGY
COMITE ASSOCIE D'HYDROLOGIE

PROCEEDINGS OF THE CANADIAN HYDROLOGY SYMPOSIUM No 17 - 1988

Canadian Research Basins: Successes, Failures and Future

COMPTES RENDUS DU SYMPOSIUM CANADIEN D'HYDROLOGIE No 17 - 1988

Les Bassins de Recherche canadiens: Succès, Eches et Futur

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FOREWORD

The 17th Canadian Hydrology Symposium was held on May 9-11, 1988, at the Banff Centre, Banff, Alberta, under the auspices of the National Research Council of Canada's Associate Committee on Hydrology. This symposium brought together most of those who have been involved in research in or management of Canada's Research Basin Program. These proceedings contain two distinct types of papers:

- Reviews of particular research basins.
- Reports on research conducted in conjunction with a research basin.

The review papers were solicited by the program committee in order to provide a written record of the many research basins that exist across Canada. Research papers were voluntary. The papers contained herein have been retyped, with minimal editing and printed essentially as they were received, without referee review. A special word of thanks goes to Pierre Bernier for his translation of most of the abstracts to French.

I wish to thank the following people whose efforts made this symposium a reality. The program committee consisted of Dave Daugharty, Eugene Hetherington, Bob Swanson and Trevor Dickinson (Chairman). Local arrangements were handled by Ron Deeprose and Judy Lindsay.

AVANT-PROPOS

Le 17ième Symposium Canadien d'Hydrologie s'est déroulé au "Banff Centre", Banff, Alberta, du 9 au 11 mai 1988, sous les auspices du Comité Associé sur l'Hydrologie du Conseil National de Recherches du Canada. Ce symposium rassemblait la plupart des personnes qui ont été impliquées dans les aspects de recherche ou de gestion du Programme Canadien de Bassins de Recherches. Ce compte-rendu contient deux types de communications:

- Les synthèses sur des bassins de recherches particuliers.
- Les présentations de résultats de recherches menées sur un bassin.

Les synthèses étaient toutes des communications invitées. Le comité du programme tenait ainsi à obtenir un compte-rendu écrit sur les activités de tous les bassins de recherches au Canada. Les communications de recherche étaient volontaires. Les communications contenues dans ce compte-rendu ont été mises en page avec peu d'édition, et ont été imprimées essentiellement comme reçues des auteurs, sans comité de lecture. La traduction au français des résumés et autres textes a été réalisée par Pierre Y. Bernier.

Je désire remercier les personnes qui ont rendu cette rencontre possible. Le comité du programme était composé de Dave Daugharty, Eugene Hetherington, Bob Swanson et Trevor Dickinson (Président). Les arrangements locaux ont été organisés par Ron Deeprose et Judy Lindsay.

R.H. Swanson
General Chairman/Président Général
Canadian Hydrology Symposium - 88/Symposium Canadien d'Hydrologie -88

PRÉFACE

En 1964, le Comité Associé sur l'Hydrologie du Conseil National de Recherches tenait un symposium sur les "bassins de recherches"[1], similaire à celui-ci, à Guelph en Ontario. Dans son allocution d'ouverture, le Dr. R.H. Clark demandait:

> La valeur de cette approche [des bassins de recherches] est-elle suffisante pour justifier l'investissement de tels montants et de tels efforts sur de si longues périodes?

Un des principaux objectifs de cette rencontre-ci sur la révision des bassins de recherches est justement de répondre à cette question.

La majorité d'entre nous qui oeuvrons en hydrologie voulons des données. Est-ce que la quantité, qualité et la pertinence des données récoltées par le programme canadien de bassins de recherches a su justifier son existence? En général, oui, malgré que le besoin en données hydrométéorologiques nouvelles sera toujours là. Mais ce besoin est sans doute moins impérieux qu'en 1964 car le programme a fourni une abondance de données sur l'hydrologie de régions, et sur les différences hydrologiques entre régions.

La majorité d'entre nous désirent une meilleure qualification du personnel. Le programme canadien de bassins de recherches a-t'il mis à la disposition des organismes responsables des ressources en eau du personnel compétent? Ces personnes utilisent-t'elles leur expertise ou ont-t'elles été détournées vers des postes administratifs? Nous pouvons sans doute dire que le besoin en hydrologistes qualifiés sera toujours là. Un des résultats du programme canadien de bassins de recherches est le grand nombre de personnes qui se disent hydrologistes.

Est-ce que nous, les hydrologistes, nous appliquons dans notre travail ce que nous avons appris grâce au programme canadien de bassins de recherches? L'étendue du Canada, la diversité de sa topographie, de son climat et de son hydrographie nous masquent souvent le fait que les principes hydrologiques de base sont les mêmes partout. Il pleut ou il neige; la transpiration des plantes transfère de l'eau du sol à l'atmosphère; l'évaporation s'effectue à partir de l'eau à la surface de la végétation, du sol, des lacs et des rivières; les eaux de surface et souterraines se drainent dans des cours d'eau coulant vers les océans d'où provient l'eau pour la pluie et la neige. Ces éléments sont connus, et la plupart d'entre nous qui avons été formés en hydrologie possédons suffisamment de connaissances ou d'expérience pour estimer l'effet d'un de ces processus sur le régime et la quantité d'écoulement d'un bassin. Appliquons nous cette compréhension du système à la gestion des ressources hydriques ou au choix d'activités de recherche?

La question du Dr. Clark restera sans doute toujours sans réponse. La valeur du programme canadien de bassins de recherches vient de ce que nous en avons appris, du degré d'application de ces connaissances à la gestion des ressources hydriques, et de ce que nous pouvons éviter de répéter suite au programme. Nous devons nous servir de l'expérience et des données acquises à la fois comme base et comme point de départ pour les activités en hydrologie.

R.H Swanson
Président Général
Symposium Canadien d'Hydrologie - 88

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CANADIAN HYDROLOGY SYMPOSIUM (CHS:88)
ASSOCIATE COMMITTEE ON HYDROLOGY
NATIONAL RESEARCH COUNCIL OF CANADA
MAY 9-11, 1988
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SYMPOSIUM CANADIEN D'HYDROLOGIE (SCH:88)
COMITÉ ASSOCIÉ D'HYDROLOGIE
CONSEIL NATIONAL DE RECHERCHES CANADA
LES 9-11 MAI 1988
BANFF, ALBERTA

Lake hydrology studies in the Mackenzie Delta, N.W.T.[1]

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ABSTRACT A study of lake basins in the Mackenzie Delta, N.W.T. was initiated in the early 1980's with the aim of providing an understanding of the hydrological processes controlling lake levels. This research originated in response to proposals of hydroelectric development in the Mackenzie Basin and the subsequent concern over the effect on lake levels and the resultant ecological consequences in the Delta. A research basin was used because it was felt that this would provide the necessary comprehensive information on the processes controlling lake levels. The principal disadvantage was that a single research basin could not deal with the spatial variation in lake regime, both within small areas in the delta, and over the entire 200 by 60 km extent of the delta. Since it was impossible to fully instrument enough basins to provide a representative sample of lake types, three other studies were designed to provide information on the spatial variability of lake regimes. First, less detailed basin studies were carried out at three sites within the delta to determine changes in lake regime over the north-south extent of the delta. Second, aerial photographs were taken across the southern, middle, and northern delta during the spring period to document ice break-up, an important process controlling water levels in the main channels. Third, measurements of lake elevation, in conjunction with analysis of 25 years of water level data provided information on the spatial variation in lake flooding within a single area of the central delta. Only by carrying out this series of integrated studies were we able to meet the overall objectives of this study.

RÉSUMÉ Au début des années '80, on a mis sur pied une étude de bassins avec lacs dans le delta du Mackenzie, T.N.O., afin de mieux comprendre les processus hydrologiques qui contrôlent le niveau des lacs. Cette recherche faisait suite aux inquiétudes concernant l'influence de projets de développement hydroélectrique proposés pour le bassin du Mackenzie sur le niveau des lacs et les conséquences écologiques de cette influence sur le delta. L'approche par bassin fut retenue car il semblait que cette approche fournirait de l'information détaillée sur les processus contrôlant le niveau des lacs. La lacune principale était qu'un seul bassin de recherche ne pouvait tenir compte des variations spatiales des régimes lacustres, variations à l'intérieur de régions du delta, et à la grandeur du delta de 200 par 60 km de superficie. Comme il était impossible d'instrumenter assez de bassins pour obtenir un échantillonnage représentatif, trois autres études ont été mises sur pied afin de cerner la variation spatiale dans le régime hydrique des lacs. Premièrement, trois autres bassins du delta ont été étudiés de façon moins exhaustive afin de déterminer les changements des régimes lacustres du nord au sud du delta. Deuxièmement, des photographies aériennes de la debâcle printannière, un important facteur dans le contrôl du

[1] NHRI contribution No. 88032.

niveau des lacs dans le chenal principal, ont été obtenues pour des sections localisées dans les parties nord, sud et centre du delta. Troisièmement, des mesures d'élévation des lacs, conjointement à l'analyse de 25 ans de données sur le niveau des eaux, a fourni de l'information sur l'inondation des lacs dans une région du centre du delta. Ce n'est que par la réalisation de ces études intégrées que nous avons pu atteindre les objectifs de base de l'étude.

INTRODUCTION

In the late 1970's B.C. Hydro proposed the development of two hydro-electric dams on the Liard River (B.C. Hydro, 1981). It was soon realized that the resulting changes in the hydrologic regime of the Liard River could be wide ranging and might even affect the Mackenzie Delta, over 1700 km downstream. Although the nature of the resulting changes, in both the physical and biological systems, were not well understood, there was considerable concern over the possible effect of the proposed Liard development on the Mackenzie Delta ecosystem. The validity of such concerns was illustrated by the Peace-Athabasca Delta experience in the 1960's and 1970's where decreased water levels resulted in significant environmental problems (Peace-Athabasca Delta Project Group, 1973). As was the case in the Peace-Athabasca, the primary uncertainty regarding potential impacts for the Mackenzie Delta focused on the effect of flow regulation on water levels in the vast number of delta lakes. These lakes, which cover approximately 25% of the Mackenzie Delta, support large and diverse populations of plants, fish, and wildlife, and are an important staging and nesting area for waterfowl. If a significant decrease in lake levels occurred, it was postulated that there would be a severe decline in the wildlife populations with resulting implications to the economy of the five communities in the Mackenzie Delta region.

In light of these environmental concerns, a study of lake hydrology in the Mackenzie Delta, N.W.T. was initiated in 1980 by the National Hydrology Research Institute. The principal objective was to improve the understanding of the hydrological processes controlling lake levels to allow water resource managers to make responsible and informed decisions with regard to development in the Mackenzie River Basin.

Specific objectives of the initial lake hydrology project were to:

(1) determine the relative importance of the various processes controlling lake levels;
(2) describe the spatial and temporal variations in hydrologic regime of the delta lakes, and
(3) develop a predictive model of lake levels.

Further work has since aimed at determining the influence of the hydrologic regime on the sediment and nutrient balance of delta lakes, which has important implications for the biological productivity of the lakes.

RESEARCH PLAN

In devising an experimental plan, the decision was made to establish a research basin in the Mackenzie Delta where detailed work could be carried out within a small, "representative" basin. It was felt that this approach would provide the necessary information on the hydrologic processes controlling lake levels. In the early 1980's, the "NRC Lake" basin (Fig.1 and 2) was chosen as a research site because it had a well-defined basin and the elevation with which it is perched above the main channel system was equal to the mean for

lakes in this part of the delta. In addition, Johnston & Brown (1964) carried out detailed permafrost studies at this site. Because of the proximity of NRC Lake to Inuvik, the long-term climate and water level records available from the Atmospheric Environment Service and Water Survey of Canada were considered to be representative of conditions at the study basin. At the NRC Lake site, studies of water level, snow-melt run-off, flooding by the Mackenzie River, flow in reversing lake channels, evaporation, ground water flow, lake water balance, and sedimentation are ongoing. The instrumentation and analysis techniques used in these studies have been described in Marsh (1986, 1988), Marsh & Bigras (1988), and Marsh & Ferguson (1988).

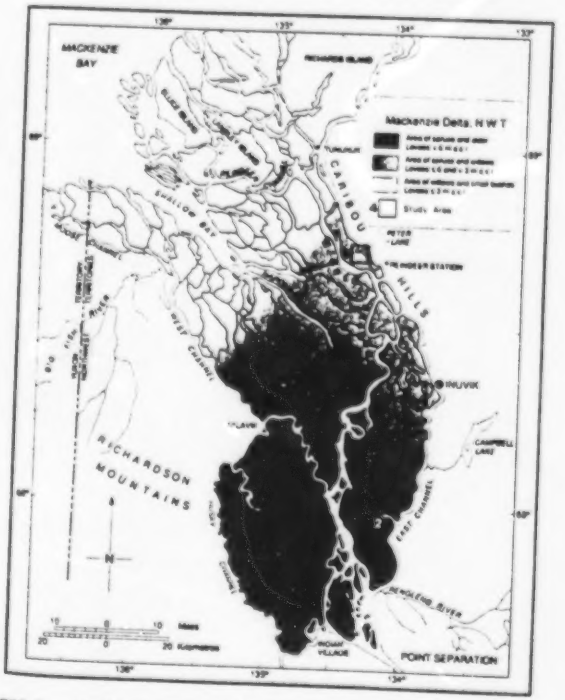

FIG.1. Location of study sites in the Mackenzie Delta. NRC Lake research basin is located in area 4, near Inuvik.

It was realized, however, that because of the unique aspects of the delta, a single research basin would not allow us to meet all of our original

objectives. The primary problem was the tremendous spatial variation in lake regimes. Within small areas of the delta, lake regime varies with lake elevation relative to the main channels. Over the north/south extent of the delta, it varies due to changes in levee height, discharge regime of the main channels, ice jamming, and the influence of storm surges in the Beaufort Sea.

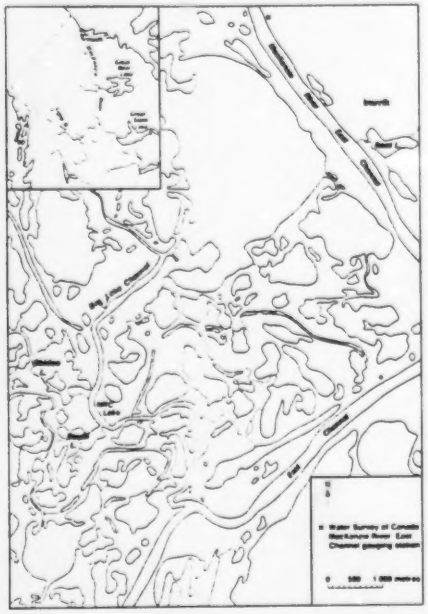

FIG.2 Location of NRC Lake in study area 4 near Inuvik, N.W.T. Note the large number of lakes, small lake sizes, and the large network of chanels which link many of the lakes. Also shown are the other study lakes within area 4.

The solution to the problem of spatial variation, was the establishment of three other studies designed to complement and enhance those at the NRC Lake research basin, thus forming an overall framework of delta hydrologic studies. First, less detailed small basin studies were initiated at three research areas located approximately 100 km apart (Fig.1). Within each area, two lakes were chosen. One low-elevation or connected lake, and the other a higher-elevation or perched lake. At each of these sites, basic data such as water level, snow cover, ice thickness, water and air temperature, and precipitation were collected. The methodology utilized in these studies has

been described in Bigras (1986, 1987). Second, in conjunction with visual observations of ice conditions, aerial photographs were taken across the southern, middle, and northern delta during spring break-up. This provided a description of the spatial and temporal variations in ice jamming, an important process controlling water levels during the spring ice break-up. These studies have been described by Bigras (1988). Third, measurements of the elevation of over 130 lakes in Area 4, were combined with the analysis of 25 years of Mackenzie River East Channel water level data, to provide information on the flooding regime of the complete elevation range of lakes in this area of the delta. The techniques used have been described by Marsh & Hey (1988).

RESULTS

These series of studies have allowed us to make significant advances in our understanding of the hydrologic regime of delta lakes, and to meet most of our original goals. In order to demonstrate the advantages of the integrated approach, the following section will briefly outline the results from a single aspect of this study, the dominance of spring flooding and spatial variations in its magnitude.

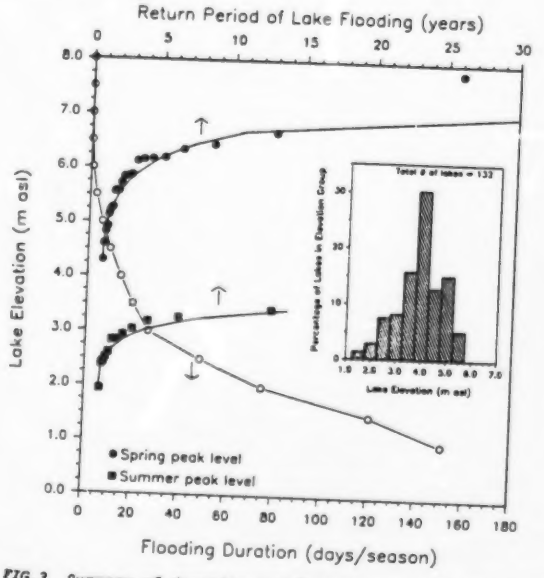

FIG.3 Summary of duration and frequency of lake flooding as determined from 25 years of record for East Channel at Inuvik and the elevation of lakes in area 4.

The studies at the NRC Lake research basin and at the less detailed basins have clearly demonstrated that spring break-up dominates the hydrologic regime of the delta, with the spring peak water levels in the main channels always greater than the summer peak water levels (Fig.3 and 4). During this period of high water levels, water enters the delta lakes through small channels connecting the lakes to the main Mackenzie River channels. This discharge dominates the lakes water balance. Detailed water balance studies at NRC Lake have shown that without this influx of water from the Mackenzie River, NRC Lake would experience a negative water balance, and declining lake levels. This would occur for two reasons. First, lake evaporation is larger than the open water period precipitation, and almost as large as the mean annual precipitation recorded at the Inuvik A.E.S. weather station. Second, snow-melt run-off is negligible because of the high infiltration capacity of the frozen soils. The only documented example of declining lake levels over a number of years is for a lake in Area 2. It was last flooded by the Mackenzie River in 1982, and the lake level declined about 2.5 m between the spring of 1982 and the fall of 1985.

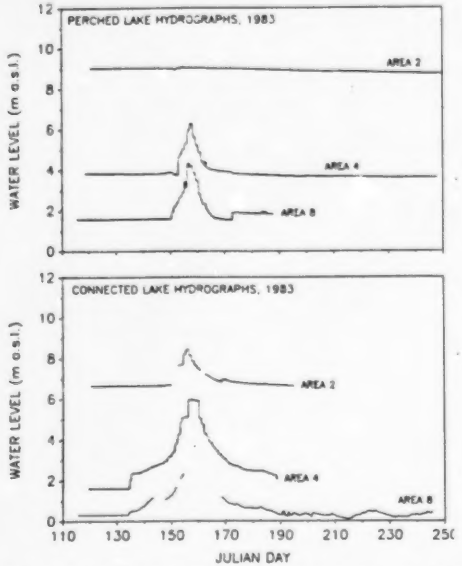

FIG.4 Lake levels for connected and perched lakes in areas 2, 4, and 8 in 1983.

Within a given study area, the main factor controlling channel discharge into the lakes is the lake elevation, with inflow decreasing with increasing lake elevation. This variation in discharge regime is illustrated in Figure 3,

which provides data on the frequency and duration of lake flooding versus lake elevation and the percentage of lakes in each elevation band. In this example, lake flooding is defined as occurring when the main channel water level is above the lake elevation, and discharge is into the lake through the lake connecting channel. Using Area 4 as an example, Fig.3 shows that the return period of lake flooding in the spring varies from annually for the 67% of all lakes below 4 m asl, to every 4 years for the highest elevation lakes. Fig.3 also shows that the duration of flooding decreases rapidly with increasing lake elevation.

Similar variations in regime also occur over the north-south extent of the delta. They are due primarily to changes in levee heights from 10 m a.s.l. in the southern delta near Area 2 to less than 3 m a.s.l. in the northern delta (Area 8). As a result there are substantial variations in the main channel regime, lake elevations, and therefore in lake regime. For example, lakes in the southern delta are at a higher elevation, and are the last to experience the effects of back-water flooding in the spring, and have the smallest increase in water level (Fig.4). The highest elevation lakes in this area are flooded infrequently and experience declining water levels over the summer period (Fig.4). As you move further north to the central delta, the lakes are lower in elevation, are flooded earlier and consistently experience the greatest water-level fluctuations (Fig.4). Lakes in the northern delta (Area 8) have much lower elevations and are among the first to be flooded in the spring (Fig.4). The increase in water levels from late winter values to peak flood levels is greater in the northern than the southern delta, but not as great as the central delta.

The primary conclusion from these results is that delta lakes rely on spring flooding by the Mackenzie River. If the spring water levels in the main Mackenzie Delta channels are reduced due to hydro-electric development, lakes would flood less frequently and would experience declining water levels or might even disappear completely. This would have serious consequences for wildlife in the delta. The higher elevation lakes which currently do not flood annually in the spring are the most sensitive to changes in the Mackenzie River spring water level regime. These include about 30% of lakes in Area 4 and the majority of lakes in Area 2. There are few, if any lakes of this type in Area 8.

DISCUSSION

Our work in the Mackenzie Delta has illustrated both the advantages and disadvantages of the research basin approach in an environment such as the Mackenzie Delta. It has proven very successful in documenting the magnitude and relative importance of processes such as snow melt run-off, lake evaporation, ground-water flow, and channel discharge for a single lake. This could not have been achieved using any other approach. However, due to financial and logistical restrictions which limited the number of research basins that could be instrumented, it was not possible to deal with the spatial variation in lake regime using the research basin approach alone. This problem was partially solved by using an integrated series of studies, of which one component was a research basin. However, our analysis of the spatial variations in lake flooding was limited by two factors. First, the lack of appropriate satellite remote sensing techniques for recording the progression of lake flooding during the spring breakup period. Unfortunately, a satellite is not yet available which can meet our requirements for all weather operation, repeat imaging every few days, and a spatial resolution of 20 to 50 m. The second limitation is the lack of long-term water-level data for the main channels in the Mackenzie Delta. Only East Channel at Inuvik has sufficient data for a

statistical analysis. It may be possible to overcome this problem using lake sediment cores to provide proxy data. This work was initiated last year.

These delta hydrologic studies are continuing, with initial results described in a number of reports and papers referred to earlier in this paper. Because of the importance of the hydrologic system to the Mackenzie Delta ecosystem, these hydrologic studies have been used by other delta researchers for environmental assessment (B.C. Hydro, 1985; Mackenzie River Basin Committee, 1981), and limnological studies (Fee et al., 1988). From a management point-of-view, the postponement of the B.C. Hydro Liard River project has delayed the requirement for decisions concerning hydro-electric development in the Mackenzie Basin. However, since other environmental issues, such as hydrocarbon development and rising sea level, have become prominent in the last few years, the need to properly manage the water resources of the Mackenzie Delta is still a prime concern. The work provided by the studies described in this paper will enhance our capabilities to provide the required scientific advice on environmental problems related to the water resources of the Mackenzie Delta.

ACKNOWLEDGMENTS

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